Quantifying Packaging's Potential to Prevent Food Waste

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American Institute for Packaging and the Environment

ACKNOWLEDGEMENT

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Executive Summary

The purpose of this report is to illustrate the significant role that packaging can play in reducing the over 62 million tons of food waste that occurs annually in the United States (US). The opportunities realizable by introducing more effective packaging is illustrated by the percentage of total available food wasted at solely the consumer level in North America and Oceania (of which the US represents ~80 percent of the region's population) exceeding the total percentage of available food loss and waste estimated to occur along the entire value chain in other regions of the world.

Food waste comprises the loss of food that is suitable for human consumption or is fit for consumption after processing (such as wheat) at any point along the value chain. This report focuses on ways to reduce waste occurring in retail, foodservice and amongst consumers through optimized[a] packaging. Optimized packaging relates to 1) the packaging of unpackaged products, and 2) improving existing packaging materials or design.

The report commences by placing the present levels of food loss and waste occurring in the US in context. The highest incidence of waste by volume occurs in fruits and vegetables. The highest incidence of waste by value occurs in meat. The least packaged foods are fruit, followed by vegetables, baked goods, meat, seafood, dairy and eggs. While a clear-cut case of cause and effect cannot be drawn, the results show that a strong correlation exists between those fresh foods that experience the highest incidence of waste and those food types that are least likely to be sold prepackaged. At an average of 46.4 percent, the incidence of US fresh foods sold in packaged form is considerably lower than that sold in comparable jurisdictions. For example, the percentages of 2016 fresh food sold in packaged form in France, UK and Germany were 55.5, 60.7 and 74 percent, respectively. In Australia, 49.5 percent of 2016 fresh foods sales were sold prepackaged.

With packaging offering a significant opportunity to reduce the unnecessary discarding of fresh foods, particularly those exhibiting a shelf life of less than 30 days, the most recently available data was used to estimate waste in the four categories of fresh foods: 1) fruits and vegetables, 2) bread/bakery, 3) meat, 4) dairy and eggs. The waste in these products occurring in retail, foodservice and amongst consumers equates by volume and value to 50.89 million tons and $186.6 billion dollars, respectively. These figures do not include additional costs associated with food waste. In retail and foodservice, they include transaction costs, lost revenue and disposal costs. Disposal costs are also incurred from consumer-generated waste, often charged in the form of municipal taxes.

A review of packaging innovations identified that packaging plays an essential role in protecting the safety, quality and shelf life of food purchased from retail and foodservice. Packaging also plays an essential role in conveying important information to consumers on storage and handling. Together, these factors lead to packaging enabling food products' shelf life to be extended by days and weeks,

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[a] The term "optimized packaging" describes achieving a balance between minimizing food waste and minimizing the environmental impacts of food and packaging waste. For example, see WRAP.

even months. A study estimated that one additional day's shelf life could annually reduce avoidable food waste in UK households by 200,000 tonnes. This equals close to five percent of overall UK food waste. Businesses benefit from the additional day's shelf life leading to increased sales and reduced costs, and consumers using the savings from not wasting food to trade up to higher value products.

Much of society has a misinformed perspective of the carbon footprint of food versus the carbon footprint of packaging. Improved packaging would produce significant environmental benefits. Consumers represent the source for the majority of US food waste. Due to factors including the energy bound up in the distribution, storage, preparation, cooking and serving of food that is ultimately discarded, consumers also represent the most carbon intensive point of the value chain. Typical ratios of the carbon footprint of foods compared to their packaging are 624:1 for cooked ham, 370:1 for beef, 178:1 for English cucumber, 114:1 for whole chicken and 52:1 for cheese.

Findings from the analysis and reviews guided the development of the consultation process with industry experts and researchers to provide an indicative assessment of the role packaging can play in reducing US food waste. Forty-five expert respondents participated in the consultations, resulting in the development of a voice of the customer (VOC) matrix, which identified packaging attributes that have a significant impact on reducing waste in each of the foods researched. VOCs provide a valuable springboard for translating market requirements into product designs and services.

Aggregated across the four categories of fresh food researched (fruits and vegetables, bakery, meat, dairy), the greatest impact that the respondents believe packaging could have on food waste is from increasing shelf life, followed by improved portion control, decreased leakage/spillage and decreased damage. In terms of the relative importance of packaging attributes for driving reductions in food waste, respondents deemed that the most impactful was the use of passive packaging technologies (e.g. MAP), followed by a) the packaging of previously unpackaged products, b) stronger secondary or tertiary packaging, c) reclosability, and d) changing to alternative packaging materials. These attributes do not occur in isolation of each other; their accumulative effect on driving reductions in food waste must not be underestimated.

The report concludes with a conservative estimate of the impact packaging could have on reducing US food waste in retail, foodservice and homes. Optimized packaging and the packaging of foods currently sold loose could produce a 20 percent reduction in fruits, vegetables and meats wasted. In bakery and dairy – where there is a higher incidence of already packaged products and potentially a marginally lower incidence of damage due to erroneous handling, which make them less perishable – an achievable scenario is a 10 percent reduction in food waste from optimized packaging. This equates to a reduction in food waste of 7.68 million tons, equivalent to the weight of 21 Empire State buildings and worth a total of $30.58 billion dollars. The environmental benefits produced by a 7.68 million ton reduction in food waste equate to a $1.98 billion reduction in GHG and saving the water contained in just under 358,000 Olympic swimming pools.

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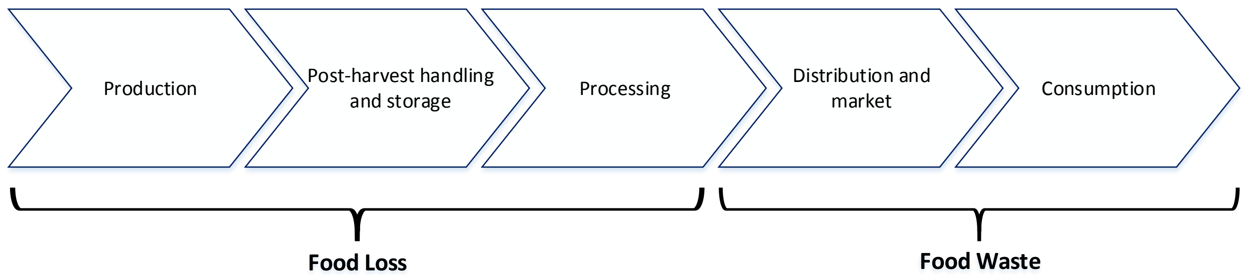
1 Introduction

The purpose of this report is to provide an objective, indicative perspective on the role that packaging can play in reducing food waste in the United States (US) at retail, in foodservice and amongst consumers. Food waste is the loss of food that is suitable for human consumption or is fit for consumption after processing (such as wheat) at any point along the value chain.[1] As the analysis of food loss and waste has evolved internationally (as shown below in Figure 1-1), the term "food loss" is typically used to describe the discarding of food that occurs from production through to processing, while the term "food waste" describes the discarding of food during its distribution and marketing to consumers through retail or foodservice and subsequently in the home.

Figure 1-1: Commonly Accepted Distinction between Food Loss and Food Waste



Packaging directly impacts the amount of food waste occurring along the value chain[2] and in US households.[3] Along with protecting food from contamination, extending shelf life and portion sizing are examples of how packaging can reduce food waste. However, efforts designed to address food waste are "in their infancy in the US."[4] This infancy is illustrated by the US trailing Europe in introducing packaging innovations designed to reduce food waste along the value chain and amongst consumers in the home.[5]

The costs associated with food waste can exceed the collective margin of the companies operating along the value chain.

Between 31 and 40 percent of the post-harvest food supply goes to waste in the US.[6] Costs associated with food waste can increase prices by 20 percent or higher,[7] negatively impacting the availability of affordable food and creating food insecurity issues.[8] The costs associated with food waste can also exceed the collective margin of the companies operating along the value chain.[9] In addition to economic considerations, the environmental impacts of food waste are tremendous.[10] Wasted food in North America/Oceania accounts for an estimated 35 percent of freshwater consumption, 31 percent of cropland, and 30 percent of fertilizer usage.[11] Food waste also accounts for 2 percent of US greenhouse gas emissions.[12] In 2012, food waste accounted for 21 percent of municipal solid waste going to landfill.[13] This estimate may include some packaging.

Food waste can be categorized as unavoidable and avoidable. Unavoidable food waste includes meat or fish bones and fruit or vegetable peelings removed during preparation or at meal time. Avoidable food waste is where once perfectly edible foods are not consumed; for example, due to reaching a stage at which they are unsafe to consume or becoming aesthetically unappealing. Precise estimates do not exist on the percentage of unavoidable versus avoidable food waste occurring in the US. The further foodstuffs move along the value chain, the lower the incidence of unavoidable food waste as a percentage of overall food waste. Hence, the incidence of unavoidable food waste as a percentage of overall food waste is comparatively small in retail, foodservice and households compared to (for example) farming and the food processing sector.

Packaging is a valuable means of proactively reducing food waste, but that role is frequently not understood.

This report commences by estimating US food waste occurring in retail, foodservice and individual households. Estimates are then provided on the percentage of each category of food supplied (and therefore typically sold) to consumers as pre-packaged items versus loose (unpackaged). Packaging is a valuable means of proactively reducing food waste, but that role is frequently not understood. By focusing on those factors determining the effectiveness of packaging to reduce food waste, a methodology is presented for estimating the costs and benefits achievable through using packaging. The report concludes by presenting results from consultations with industry and packaging experts, to assess packaging attributes that would have the greatest impact on driving reductions in US food waste.

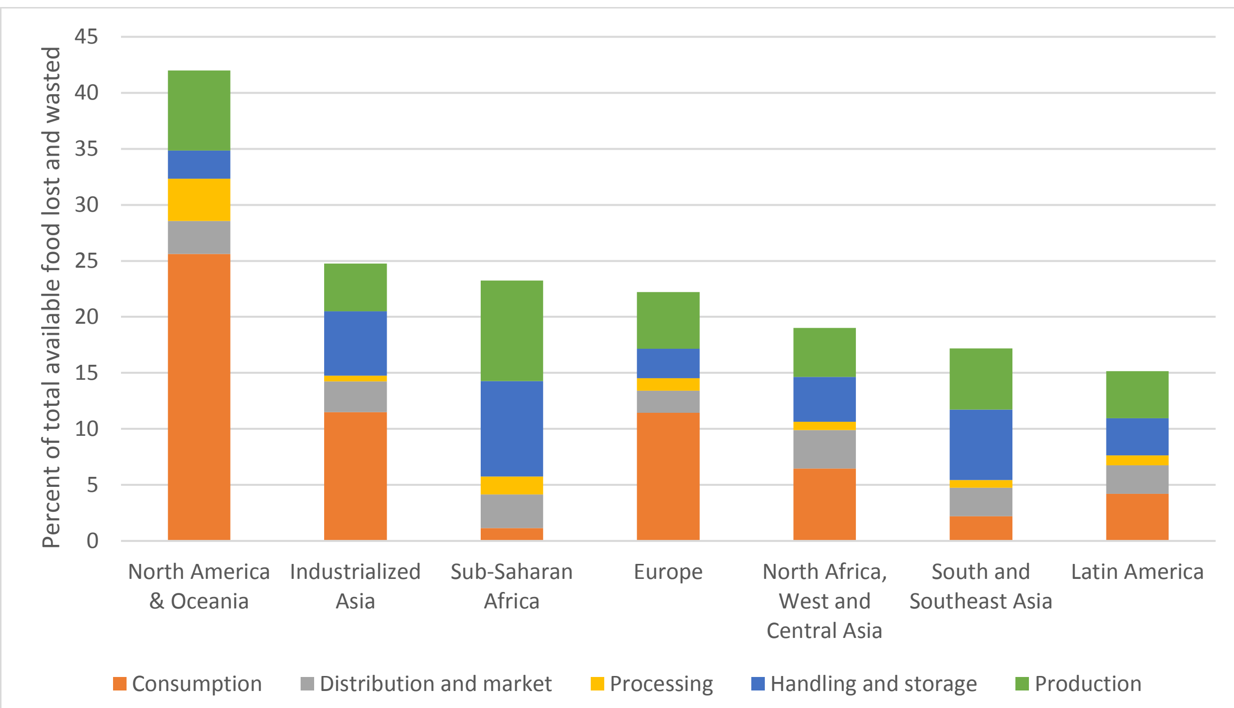
2 US Food Waste

The following section presents estimates on the weight and value of food waste occurring in the US. Packaging offers a particularly valuable role in 1) assisting businesses and consumers to reduce waste in more perishable fresh foods, and 2) meeting increased consumer demands for fresh foods compared to shelf stable ambient foods or frozen foods.

2.1 US Food Waste: Overall

The scale of the US food waste problem is emphasized below in Figure 2-1. Compared to other regions of the world, at 42 percent, the gross amount of food lost and wasted that occurs along the value chain in North America and Oceania (NAO) is significantly higher than elsewhere.[14] The NAO region comprises the US, Canada, New Zealand and Australia.[15] Compared to the region exhibiting the second highest incidence of food loss and waste (Industrialized Asia at 25%), the NAO experiences 68 percent greater food loss and waste of total available food.

Figure 2-1: Percent Kcal of Total Available Food Lost or Wasted along the Value Chain, 2009



Adapted from Lipinski et al, 2013

The percentage of available food waste that occurs amongst NAO consumers exceeds the total percentage of available food that is lost or wasted along the entire value chain in other regions.

The most telling difference between the NAO and other regions of the world is consumer waste. The percentage of available food waste that occurs amongst NAO consumers exceeds the total percentage of available food that is lost or wasted along the entire value chain in other regions. Approximately 80 percent of the NAO population live in the US.[16] This, and the fact that the majority of US food waste is disposed of in landfills,[17] means that food loss and waste represents an enormous unnecessary economic and environmental cost to US society. The highest incidence of NAO consumer waste occurs in cereals and fish/seafood.[18]

Drivers behind the consumer waste occuring in NAO versus other regions are believed to include a greater propensity to buy food from retail in bulk, due to lifestyle and the distances traveled to purchase foods.[19] This, combined with the heavy discounting and promotion of products in retail[20] and shopping behaviors shaped by attitudes of affuence and abundance,[21] results in consumers buying beyond their needs and mishandling food because it is not considered a valuable resource.[22]

Other potential reasons for NAO experiencing higher levels of waste than other regions are the comparative importance of foodservice versus retail. Key drivers of food waste in US foodservice include serving size, holding practices and menu design.[23] The inability to source ingredients in portions that match recipe requirements, in packages designed to ensure safe storage and retain freshness after opening, drives waste during the food preparation.[24] The location of restaurants in relation to residential housing also drives consumer waste, particularly from the standpoint of impulse dining or the purchasing of takeout, while food purchased from retail stagnates in the home.[25]

Presented below in Table 2-1 are ReFED estimates on the amount of US food waste generated by stakeholder source. ReFED baseline US food waste data is based on a methodology rooted in waste generation rates for key industries and per capita generation for households.

Table 2-1: ReFED Summary of Waste Generation

VCMI Classification	**ReFED Category**	**Landfill %**	**Total %**	**Total (tons/yr)**
Household	Residential	51%	42%	26,560,793
Foodservice	Restaurants	22%	*18%*	*11,443,712*
	[*Full service restaurants*]	*[14%]*	*[12%]*	[7,318,772]
	[*Limited service restaurants*]	*[8%]*	*[7%]*	[4,124,942]
Retail	Supermarket, distribution and grocery stores	15%	13%	7,972,268
Foodservice	Institutional	9%	8%	4,912,908
Other	Industrial / manufacturing	2%	2%	1,065,000
Other	Government	1%	1%	488,965
	Total Landfill Losses	**100%**	**--**	52,443,648
	On-farm losses	--	16%	10,100,000
	Total US Food Waste	--	**100%**	**62,543,648**

Source: Adapted from ReFED Technical Appendix, 2016.

ReFED categorized food waste in five categories:

- grain products
- meat
- fruit and vegetables
- seafood
- milk and dairy

2.2 US Food Waste: Retail, Foodservice, Consumers

To enable an accurate estimate of the impact of packaging on reducing food waste in retail, foodservice and households, the authors reviewed analyses from Buzby et al and ReFED[26] to identify the categories of waste occurring. The calculations of food waste by volume are the ReFED estimations minus the 1.5 million tons apportioned to “other” institutional sources.

ReFED’s categorization of waste by food type was more granular at the retail and consumer level of the value chain than foodservice. Estimating the impact of packaging on US food waste required an estimation of the volume of food waste by type created by retail, foodservice and consumers. The foodservice sector comprises a wide range of formats, from full service dine-in restaurants and public and private institutions’ dining facilities and cafeterias through to quick service “takeout” restaurants. The foodservice analysis was achieved by calculating the ratio of food waste estimated by ReFED to occur in foodservice compared to retail and consumer, then utilizing data and ratios produced by Buzby et al to estimate the volume and consequently the percentage of food waste in foodservice by food types. The resulting characterization of food waste by the percentage of volume is presented below in Table 2-2. As BLS data did not provide pricing for seafood, Tables 2-2 and 2-3 present only four of the five food types being researched.

Table 2-2: Food Waste Characterization (Retail, Foodservice, Consumer)

	Retail	Consumer	Foodservice
	%		
Fruit and veg	32.5	34.6	33.9
Grain	24.4	17.5	19.7
Dairy and eggs	33.9	28.4	30.1
Meat[b]	9.2	19.5	16.3
TOTAL	100.0	100.0	100.0

Source: Adapted from ReFED (2016), Buzby et al (2014)

The calculations of the value of food waste are based on ReFED[27] methodology, updated with values contained in the 2016 Average Retail Prices produced by the Bureau of Labor Statistics (BLS).[28] When estimating the values within the categories, the focus was on fresh products. In grains, for example, this enabled a delineation to be established between bread versus rice or flour. USDA food availability data was then used as a weighting to calculate a weighted average price for each of the four categories — the assumption being, the more available a food is, the more likely it is to be purchased, and, therefore, the more it will contribute to the overall price of that category. As the focus is on fresh foods, prices for processed foods were not included in price estimation. The BLS average retail prices, updated for 2016, used to calculate the value of food waste are presented in Table 2-3.

Table 2-3: Updated Values for Food Types for 2016

	Retail Value ($/lb)
Fruit and veg	1.30
Bread	1.67
Dairy and eggs	1.14
Meat	4.33

Source: Bureau of Labor Statistics (2016)

[b] Includes fish and seafood. Seafood was not separated from meat for this study because there was no reasonable price data available to allow for it to be analyzed at this level of detail.

Table 2-4: US Food Waste Estimation by Value ($ Billion) and Volume (Million Tons) for 2016

	FW retail		FW foodservice		FW household		Total	
	Value	Volume	Value[c]	Volume	Value	Volume	Value	Volume
Fruit and veg	6.73	2.59	14.40	5.55	23.82	9.18	44.95	17.33
Bread/bakery	6.49	1.95	10.74	3.22	15.52	4.65	32.75	9.82
Dairy and eggs	6.16	2.70	11.23	4.92	17.18	7.54	34.57	15.16
Meat	6.32	0.73	23.05	2.66	44.92	5.19	74.28	8.58
TOTAL	**25.70**	**7.97**	**59.41**	**16.36**	**101.45**	**26.56**	**186.56**	**50.89**

Source: Adapted from ReFED (2016), Bureau of Labor Statistics (2016)

From a quantity perspective, compared to other foodstuffs, fruits and vegetables represent the highest incidence of food waste in retail, foodservice and amongst consumers.[29] From a value perspective, meat represents the highest incidence of food waste in foodservice and amongst consumers. In retail, meat represents the third highest incidence of food waste by value. As a stakeholder group, consumers represent the greatest source of US food waste, annually spending on average 9.2 percent ($371) of their annual food purchases on food that they later waste.[30]

2.3 Prepackaged vs. Unpackaged Food

In order to calculate the impact that packaging could have on reducing US food waste (either by increasing the percentage of packaged food within a category or by improving the functionality of existing packaging), an estimate was calculated of the incidence of packaged versus unpackaged food. This is followed by a summary of these findings.

Euromonitor[31] provides data on packed versus unpacked products for all of the food types categorized in Section 2.1, with the exception of dairy. Table 2-5 below shows the percentage of packaged fresh foods occurring within each of the categories. The data encompasses food purchased by consumers from retail and supplied to foodservice operations. Data is not available on the percentage of prepackaged versus unpackaged food purchased from foodservice.

[c] WRAP estimated that the average value of food waste occurring in UK foodservice was three times higher than the average value of food waste occurring in UK retail (~$4,358 versus $1,413 respectively). With a comparable ratio not existing in the US, the same BLS food values were applied to both US foodservice and US retail.

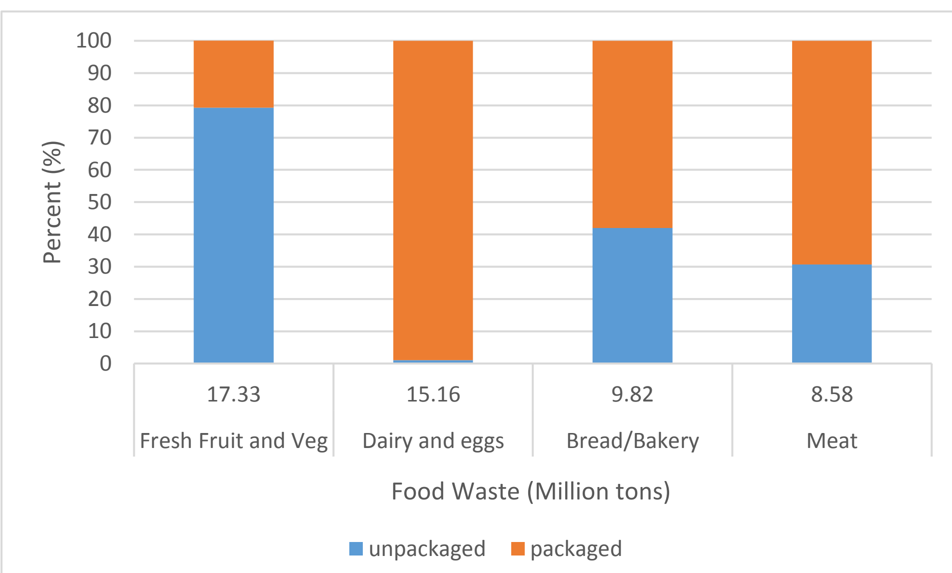
Table 2-5: US Fresh Food Sales: Packaged vs. Unpackaged (Percentage)

	Packaged	Unpackaged
Fresh fruit	14.7	85.3
Fresh vegetables	26.8	73.3
Baked goods	58.0	42.0
Meat	67.5	32.5
Seafood	71.2	28.8
Dairy and eggs*	99.0	1.0
ALL FRESH FOOD	**46.4**	**53.6**

Source: Euromonitor International, 2017 *Estimation

The granularity of data on fruits, vegetables, meat and seafood enables the incidence of prepackaged versus unpackaged foods to be presented separately. For dairy and eggs, consultation with the industry suggested that 99 percent of products sold to consumers are packaged. Whether that packaging is the prepackaged format in which milk, yogurt, cheese, etc. was received by the retail store or foodservice operation, or surround wrap type packaging applied at the location, will differ by product and outlet. The highest incidence of food purchased by consumers that is not prepacked occurs in fruit (85.3%), followed by vegetables (73.3%), baked goods (42%), meat (32.5%) and seafood (28.8%). While it cannot be presented as a clear-cut case of cause and effect, as shown below in Figure 2-2, a correlation exists between fresh foods that experience the highest incidence of waste and those food types that are least likely to be sold prepackaged.

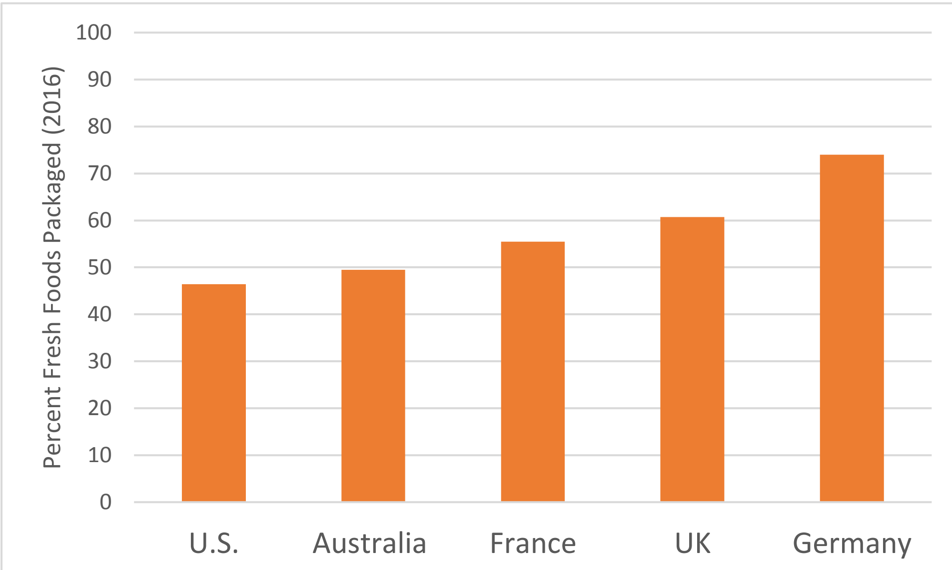
Figure 2-2: Incidence of Unpacked and Packaged Fresh Food (%) and Waste (Million Tons)



Source: Adapted from Euromonitor International (2017), ReFED (2016), Bureau of Labor Statistics (2016)

In 2016, 46.4 percent of US fresh food sales were packaged. As shown below in Figure 2-3, this is measurably less than the percentage of packaged fresh food sold in France, UK and Germany (55.5%, 60.7% and 74%, respectively). In Australia, 49.5 percent of 2016 fresh foods sales were prepackaged.[32]

Figure 2-3: Fresh Foods Sold Packaged as a Percentage of Overall Sales (2016)



Source: Euromonitor International, 2017

Euromonitor data also identified the extent to which consumer perceptions and behaviors are driving changes in the existence of packaged versus unpackaged foods. An example from the "grains" category is bread versus pastries. During 2016, US baked goods recorded a one percent growth in value and a one percent growth in volume. Packaged bread, however, posted a one percent decline in both volume and value, due to a shift away from processed foods in favor of natural offerings. Packaged pastries, on the other hand, posted an increase in both volume and value of four percent and six percent, respectively.[33]

3 The Role of Packaging in Reducing Food Waste

Packaging plays an essential role in protecting the safety and quality of food purchased from retail and foodservice, resulting in extended shelf life.[34] Packaging also plays an essential role in conveying important information to consumers about issues including use, storage, nutrition, ingredients and origin.[35]

3.1 Unrealized Potential

Packaging enables food products' shelf life to be extended from days to weeks, even by months in some cases.[36] Figure 3-1 illustrates that the use of modified atmosphere packaging (MAP), vacuum packaging and active packaging can extend the shelf life of food by a factor of two to ten times. The comparison includes gains achievable by replacing common traditional packaging, such as overwrap Styrofoam, with optimized packaging.

Figure 3-1: Extensions in Shelf Life from Packaging

One day of additional shelf life has the potential to reduce avoidable household food waste by 200,000 tonnes, equating to 5% of avoidable food waste.

With a UK study showing that one day of additional shelf life has the potential to reduce avoidable household food waste by 200,000 tonnes, equating to five percent of avoidable food waste,[37] packaging could play a considerably greater role in reducing US food waste than presently occurs. Optimized packaging also reduces food waste (often by 15% to 30% or more) through enabling more accurate portion sizing in retail[38] and foodservice,[39] and reducing damage or spillage.[40]

Compared to Europe, relatively little research and effort has been undertaken to identify key drivers of US consumer attitudes and behaviors that result in unnecessary food waste.[41] With considerable work on food packaging having been completed by UK organizations such as WRAP and INCPEN, and European organizations such as Denkstatt, in conjunction with voluntary agreements established between industry and government on developing means to reduce food and packaging waste,[d] it is perhaps not surprising that, anecdotally, Europe has been faster to adopt new packaging innovations than other regions, including the US.[42]

As much of the food consumed in the US is imported – particularly in segments such as seafood, where imports account for up to 90 percent of consumption[43] – optimizing the role of packaging to reduce food waste requires the adoption of a global perspective.

3.2 Packaging Type

Packaging can be grouped into three types (listed below), the specific role of which for reducing food waste differs according to its use in the value chain:

1. Primary or sales packaging (what shoppers take home),
2. Secondary packaging (boxes, trays, cartons often seen on retail shelves), and
3. Tertiary (or transport) packaging (large containers and pallets that allow products to be transported by truck).

A detailed discussion on each type of packaging and on optimizing their design to maximize their impact in reducing food waste while minimizing their environmental impact is beyond the scope of this report.

[d] The broadest example of a voluntary agreement between industry and government to improve resource efficiency by reducing food and packaging waste is the Courtauld Commitment. Established in 2005 and in its fourth iteration, this UK grocer industry initiative has resulted in significant reductions in food and packaging waste: http://www.wrap.org.uk/category/initiatives/courtauld-commitment.

Decisions surrounding the materials and designs chosen for primary, secondary and tertiary packaging are made on the basis of a range of criteria, including

- food safety and shelf life requirements,
- protecting the product from damage,
- consumer appeal,
- distribution requirements, and
- supporting closed loop systems by designing for recyclability and recycled content.

Packaging used in all three segments (retail, foodservice and consumer) of the value chain need to provide the right level of protection to keep food damage and waste to a minimum, while simultaneously minimizing its own environmental footprint. Packaging is unique in that its primary role is to protect another product. Since the range of products to protect are diverse, there is no single “best” material or format for all products — just an appropriate one for a quantity of a particular product in a particular application. For example, toothpaste can obviously not be packed in a paper bag; however, paper bags are perfect for flour.

3.3 Optimizing Packaging for Greatest Effect

Packaging must be optimized, by taking into account its product protection role. For example, an increase in packaging may be justified if it can lead to significant reductions in food waste. By identifying impacts across the supply chain/lifecycle, packaging re-designs and innovations can be targeted to address food waste challenges. Such a holistic approach can uncover savings and reduce overall environmental impacts.

In the UK, Northern Foods made changes to their Goodfella’s pizza packaging. Boxes developed in conjunction with their packaging suppliers reduced the number of pizzas damaged before they reached the consumer by 75 percent, thus reducing food waste.[44] This was achieved by making Goodfella's pizza boxes (primary packaging) more robust, increasing the packaging by four percent. The change, however, allowed a much larger reduction in outer (secondary and tertiary) packaging needed to transport the pizzas to retailers. Total packaging used on Goodfellow’s pizza was reduced by 4,000 tonnes per year. In addition, because the new packaging allows more efficient stacking on each pallet, the company has been able to achieve a reduction of one million transport miles annually and reduce the number of damaged pizzas reaching consumers.

Large reductions in food waste can also be achieved through small changes to packaging design. In the US, Sealed Air has shared results of a study where the percentage of 8 pound processed hams going to waste was reduced from 7.13 to 1.25 percent (equating to an 82% improvement in performance), by adding an additional layer of protection around the shank bone only. Although this additional protection increased the packaging weight by 25 percent, it resulted in a significant reduction in total environmental impact. The change followed a study showing that packaging was failing due to the bone that protruded from the shank breaking the seal.

The most effective packaging innovations occur when retailers and foodservice customers collaborate with their suppliers.

The most effective packaging innovations occur when retailers and foodservice customers collaborate with their suppliers.[45] The UK retailer Sainsbury's worked with apple suppliers to develop flow wrap packaging. More rigid than the previous loose bagging of apples, and arranged tube-like versus the previous configuration, a jumbled bag produced an 11 percent reduction in store-level waste from handling damage caused by staff and consumers. The new packaging also reduced distribution and handling costs.[46] Other large UK retailers, such as Tesco and ASDA, have adopted whole lifecycle approaches to utilize packaging more effectively and extend shelf life, resulting in a reduction of food waste along the chain and amongst consumers.[47]

3.4 Functionality

An expanding area of innovation directly related to the role of packaging to reduce food waste at retail, foodservice and among consumers is increased functionality.

An expanding area of innovation directly related to the role of packaging to reduce food waste at retail, foodservice and among consumers is increased functionality. Packaging functionality is also becoming more and more important for capturing value, by increasing consumer satisfaction for products purchased in retail stores[48] and from foodservice.[49]

Factors driving the need for more effective and functional packaging include "(a decrease in household size), more people buying smaller portions of food, higher living standards leading to the purchase of more consumer goods, transport over long distances, and higher demands for convenience and processed food."[50] Combined with consumer advice, including the design and communication of date labeling, increased functionality can have a significant impact on food waste — particularly at the household level.[51]

Examples of improved functionality include reclosable packaging. This is particularly beneficial for extending shelf life in the fridge, by preventing foods such as cheese from drying out. In the UK, a range of new types of packs designed to suit different needs has been launched. These new types include smaller packs of bread, "fridge packs" for baked beans (which last longer once opened), and packs that are subdivided so that you can use some now and some later (e.g. salads, sliced meats, bakery products). Other examples of functional packaging that can measurably extend shelf life and freshness/quality include vacuum skin packed fresh meat, along with intelligent packs to prevent fresh fruit and vegetables from over-ripening.

The potential impact the above changes could have on reducing US food waste is underlined by a survey[52] that identified the most popular changes in packaging desired by US consumers. Respondents said they "would like to see" more resealable packages (57%), more variety in product sizes (50%), "buy one, get one later" sales (48%), and discounting foods that are over-ripe or near expiration (48%). Respondents were also asked which products they would like to see sold in smaller packages. Top ranking responses included baked goods, bagged salad, bread and meat

(43%, 41%, 39% and 29%, respectively). Produce was also mentioned by respondents as an area in which they would like to see more changes in packaging.

3.4.1 Light-Weighting

Light-weighting enables increases in the amount of food packaged to be decoupled from the volume of packaging sent to landfill, reused or recycled.[53] Reducing the amount of packaging, while maintaining functionality to protect and distribute food, decreases overall environmental impacts. Light-weighting also reduces the transport, storage and handling costs associated with manufacturing and the distribution of both raw materials and food items through the value chain.

Examples of the many light-weighting design innovations that have resulted in reduced food waste include the UK retailer Marks & Spencer (M&S) reducing the packaging associated with its beef joints and steaks, Tesco's introduction of new chicken packaging, Warburtons introducing a smaller 600g bread loaf, and Fyffes developing a smaller banana carton.

M&S was looking for a solution to replace the plastic tray in which the beef joint was previously packaged, but needed to ensure that the preservation of the meat was front of mind. The solution was a "skin pack" — a type of vacuum shrink packaging that is wrapped tightly around the product, which protects the meat from spoiling. Not only does this method cut down the packaging weight by up to 69 percent, it also keeps the meat fresher for up to four extra days, which means it is less likely to go to waste.[54]

Tesco worked with their chicken and packaging suppliers to develop a new lighter FORM-SHRINK pack. Moving from a standard tray and film pack to a shrinkable bag produced a 68 percent reduction in packaging weight, while simultaneously increasing shelf life by two days.[55] In addition to reducing the volume of packaging, supply chain efficiencies were improved through increasing the number of birds contained in each crate shipped to distribution centres and onto stores. WRAP[56] completed research to reduce the weight and effectiveness of meat packaging. Shelf life was subsequently extended by replacing traditional packaging (a tray with a moisture pad with film over-wrap and attached label) with a sealed air wrap and labeling incorporated into the film.

Warburtons successfully launched a 600g sized loaf of sliced bread. The new format expands pack size choice from the traditional 800g and 400g packs, enabling consumers to tailor their purchases according to use — resulting in less bread and packaging going to waste.

Fyffes, in cooperation with Midlands Cooperative, introduced a 12kg banana carton, specifically designed to better match supply with demand in convenience stores. Smaller than the traditional 18kg banana box, the box is estimated to reduce store waste by 90 percent. Enabling consumers to purchase more consistent quality bananas is expected to reduce waste in the home also.[57]

3.4.2 Technology Innovation

Innovations are resulting in marked improvements in the value and effectiveness of packaging materials for reducing food waste. Packaging innovations can translate into retailers, foodservice and their suppliers benefiting from increased brand recognition.[58]

While an in-depth discussion of packaging innovations is beyond the scope of this project and will be included in subsequent studies, many packaging innovations can be grouped into three categories:

1. Passive packaging technologies (e.g. MAP, vacuum, controlled permeability),
2. Active packaging technologies (e.g. odor scavenging, oxygen scavenging, gas absorbers), and
3. Intelligent packaging technologies (e.g. sensors and indicators).

Technologies such as controlled permeability are increasingly being applied through the development of complex multi-layered packaging and vacuum skin or flow-form packaging. Meat is an example of where this type of packaging is increasingly being used.[59] Active packaging technologies are increasingly using nanotechnology to reduce waste, by improving food safety, extending freshness and enhancing the functionality of packaging.[60] The use of nanomaterials to improve food safety and nutritional content appeals to consumers to the point that it can translate into consumers expressing a willingness to pay higher prices for foods, such as chicken.[61] Intelligent packaging technologies include labeling (discussed below). An example of an intelligent sensor was described in PAC's 2014 review of packaging technologies designed to reduce food waste.

3.5 Barriers to Change

A lack of awareness regarding the role of packaging in reducing avoidable food waste along the supply chain amongst individual households creates a barrier to packaging playing a more impactful role in measurably reducing food waste.[62] Other barriers, including attitudes possessed by consumers and industry towards packaging and food, are briefly described below.

3.5.1 Misplaced Assumptions

Consumers commonly cite an aversion to packaging due to incorrect perceptions of its environmental impact.

Consumers commonly cite an aversion to packaging due to incorrect perceptions of its environmental impact.[63] Despite packaging accounting for only a small percentage of food products' overall environmental footprint,[64] it is a visible use of resources that attracts consumers' attention. Achieving an optimal balance between enabling packaging to play a crucial role in reducing food waste while minimizing packaging's own environmental impact is therefore critical to garnering consumer acceptance.[65]

Consumers have proven to be receptive to packaging when presented with information on the benefits.[66] The most commonly cited and impactful factors driving consumer behaviors that result in avoidable food waste are quality and safety related; hence the influence of using date labeling and perceptions of freshness to increase consumer acceptance of packaging.

In the UK, Tesco is working with WRAP[67] to help consumers "reduce food waste through improved packaging, stopping *Buy One Get One Free* promotions on fruit and vegetables, and putting *Love Food Hate Waste* tips on our *Perfectly Imperfect* range. *Love Food Hate Waste* is a much-needed campaign, and we're committed to working together to help our customers reduce waste and save money."

3.5.2 Perceptions of Freshness

Unpackaged food is often perceived to be fresher and more nutritious than packaged products.[68] Packaging itself will not have a significant influence on consumer attitudes and behaviors until its attributes are promoted: packaging helps preserve quality, freshness, nutritional aspects and taste — all these being crucial determinants of consumers' purchasing and aftermarket choices.[69] Motivating consumers to view packaging as a valuable means of storing and protecting food, resulting in less waste in the home, also relies on ensuring that the packaging reflects cultural norms — which is societal dependent.[70] Therefore, the most appealing and effective packaging for US consumers may differ quite markedly to designs that have proven effective in other jurisdictions.

3.5.3 Industry Resistance

Retailers and foodservice operators have an important, though often underutilized, role to play in driving reductions in food waste along the entire value chain, through motivating innovations in packaging design and encouraging consumer acceptance of packaging.[71] This comes in part from their ability to exert influence upstream and downstream in the supply chain. Examples of the role that retailers and foodservice operators have played in driving changes in food packaging design and utilization to reduce food waste include WRAP, IGD and Aspalter.[72]

The food industry can be resistant to playing a leading role in driving reductions in food waste. Reasons cited include what has been described as an obsession with maximizing sales volume and market share by minimizing per unit production costs and price. Market failures occur when food prices do not reflect the true cost of production.[73] During the researching of this report, a reluctance by businesses operating in the food industry to use more effective packaging (because it could lead to increased input costs, despite, in some cases, obvious cost savings from light-weighting or other innovations) was mentioned on numerous occasions.

Industry can also be resistant to introducing more effective packaging or increasing the percentage of packaged food, due to concerns that doing so will discourage consumers from purchasing their products or frequenting their store or restaurant. Resistance also stems from a belief that reducing food waste amongst consumers will negatively impact sales and, in turn, margins and profitability.[74]

The perception that packaging designed to decrease food waste increases costs or discourages consumer acceptance was an unexpected finding. The next section addresses the value (economic, environmental and social) that packaging delivers across the supply chain.

4 Quantifying the Benefits of Packaging to Reduce Food Waste

The following section describes how the benefits to industry, consumers and society through optimized food packaging can be quantified.

4.1 Monetary Benefits

The reduction of food waste represents a clear financial opportunity for consumers, businesses and industry as a whole.[75] The cost of waste occurring along a value chain can exceed the combined margins of the involved companies. In retail for example, a one percent reduction in food waste (termed shrink) can translate to the equivalent of a four percent increase in revenue.[76] Foodservice operators can benefit from food waste reduction to an even greater degree. Consumers pay for avoidable food waste in the form of potentially 10 percent or more of prices paid, along with municipalities or states charging higher taxes to help cover the cost of organic disposal.[77]

Packaging can translate into higher margins for retailers and foodservice through reducing shrink, potentially while simultaneously driving increased sales.

The World Food Preservation Centre[78] stated that the "return on investment in technologies that preserve food has been shown to be far greater than investments in food production." Packaging can translate into higher margins for retailers and foodservice through reducing shrink, potentially while simultaneously driving increased sales.[79] Improved packaging can also translate into financial savings for consumers.[80]

As described in section 3.1, improved packaging or the packaging of foods currently sold loose can extend shelf life by weeks, even months. In the UK, one day of additional shelf life was estimated as having the potential to reduce avoidable food waste by five percent. Businesses would benefit from the additional day's shelf life, leading to increased sales and reduced costs from having less waste occur within their operations. Businesses would also benefit from consumers "trading up to higher value products by using the savings they gain from wasting less food."[81] WRAP[82] estimated that investment in changing production lines to extend the shelf life of foods typically pays off in two to three years. The median monetary benefit that businesses captured through food waste reduction initiatives, including improved packaging, produces a 14 to 1 return on investment;[83] every $1 invested resulted in an ROI of $14.

As described earlier in this report, less food is sold prepackaged in the US than comparable markets, a proven relationship exists between food packaging and food waste, and considerably higher levels of available food waste occur in the US than other regions of the world. These three facts reflect the opportunities that exist to reduce US food waste by optimized packaging. The extent to which packaging could assist in reducing food waste in the US is hinted at by ReFED's[84] reference to packaging technologies that are in their infancy, though offer the potential to reduce food waste by up to 35 percent.

4.2 Resource Utilization

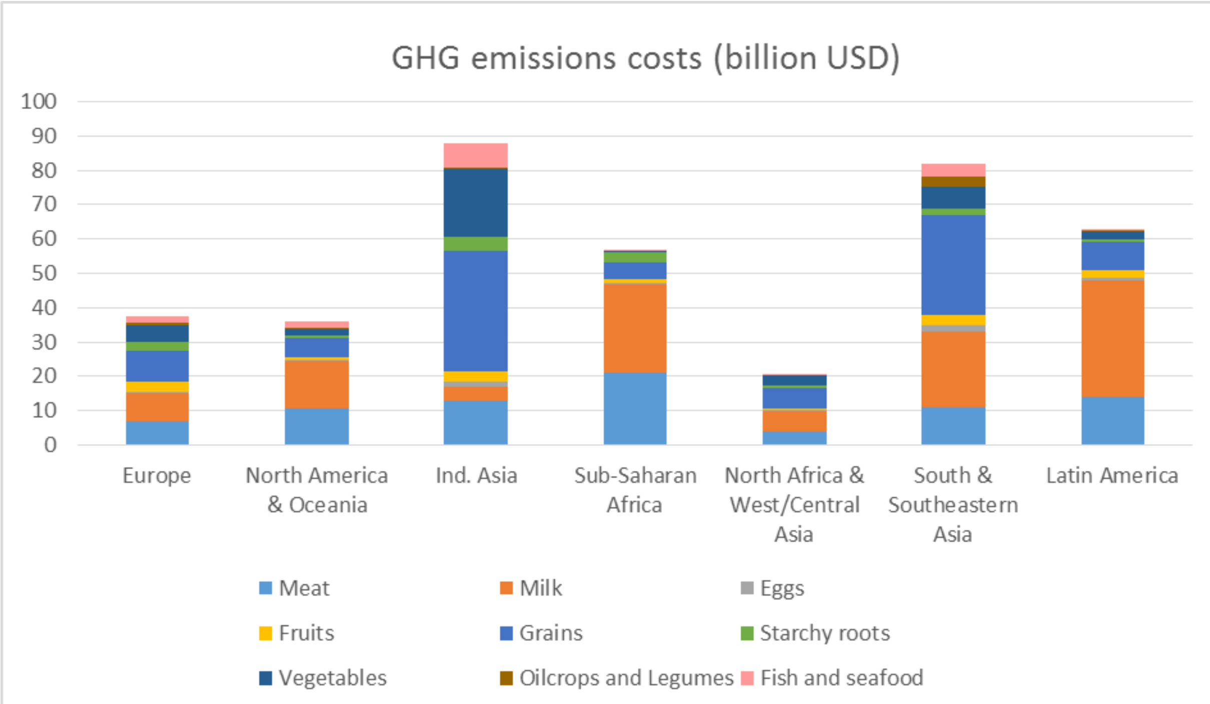
Added to the monetary savings of reduced food waste are non-financial benefits, which need to be factored into benefits achieved through reducing food waste.[85] These include stronger customer relationships, boosting of employee pride, and satisfying society's sense of ethical responsibility. Additional non-monetary effects that can be apportioned a value through environmental economic analysis are the significant natural resource related benefits achievable through reducing food waste, particularly that which is created by consumers.[86]

Approximately eight percent of total anthropogenic GHG emissions are from global food loss and waste. This is similar to the volume of GHG produced from global road transportation

Food loss and waste represents an inefficient use of natural resources. It also represents a significant contribution to GHG emissions, due to the energy and resources bound up into the production of products that ultimately become waste.[87] The FAO reported that approximately eight percent of total anthropogenic GHG emissions are from global food loss and waste. This is similar to the volume of GHG produced from global road transportation.[88]

Figure 4-1 illustrates the significant cost of GHG emissions from food waste in all regions of the world, particularly the cost that emanates from meat, milk and grains. In presenting GHG from a whole of chain (food loss and waste) perspective, differences in GHG emissions illustrate variations in the carbon intensities of food production systems. For example, vegetables grown in greenhouses have higher carbon intensity than field production, and rice is a higher emitter of GHG due to emissions of methane from the rice paddies.[89] As can be seen in the chart, these costs for North America and Oceania are approximately $10 billion, $15 billion and $5 billion for meat, milk and grains, respectively. These three product types constitute the majority of GHG emissions and therefore present a significant opportunity for mitigation. Though meat represents a relatively small volume of waste globally, the GHG emissions are substantial, due to the cumulative effect of emissions from ruminants, livestock feed production and manure management.[90]

Figure 4-1: FAO Calculation – The Cost of GHG Emissions from Food Waste[e]



Source: FAO (2014)

As has been previously demonstrated, the majority of the food waste in North America occurs at the consumption stage of the value chain. With this being the most carbon intensive point of the entire value chain – due to factors including the distribution, storage, preparation, cooking and serving of food that is not consumed – packaging that prevents consumer wastage will likely have the most impact on reducing the carbon footprint of food waste.[91] In meat, for example, vacuum packaging can have a significant impact from economic, social and environmental perspectives by reducing cost and impact of food waste while increasing value to consumers. Through the use of vacuum packaging, the shelf life of fresh meat can be extended, and the subsequent spoilage across the supply chain reduced. Consumers can benefit by having more time to consume fresh meat products before they start to spoil.

For reasons cited above, a reduction in food waste directly translates to a reduction in foods' environmental impact, or "carbon footprint."[92] Although improved packaging – resulting in better protection of the product and/or an increase in shelf life through other means – or the packaging of currently unpackaged foods will produce a carbon footprint that may be higher than that associated with traditional or the previously used packaging, the enormity of gains achieved by having dramatically reduced food waste heavily outweighs packaging's footprint.[93] Table 4-1 presents examples of packaging improvements that resulted in reduced food waste and hence a reduction in

[e] GHG emissions valued at \$113 (USD 2012)/tCO_2e and valuation method used was the social cost of carbon (damage costs/defensive expenditure).

overall carbon footprint. Table 4-2 presents as ratios the order of magnitude between the typical carbon footprint examples of food versus the carbon footprint bound up in those same products' packaging.

Table 4-1: Examples of Impact of Packaging Innovation on Carbon Footprint, per 1,000 units

Product	Product Weight (per unit)	Packaging Innovation	Reduced Food Waste kg CO_2	Packaging Change kg CO_2	Net Overall Impact kg CO_2
Ham	8 lb	Puncture Protection	-1,024.0	21.5	-1,002.5
Pasta	9 oz	Oxygen Scavenging	-18.6	4	-14.6
Chicken	3.3 lb	Odor scavenging	-132.3	0	-132.3
Beef	12 oz	Vacuum pack	-343.0	24.5	-318.5
Fish	14 oz	Vacuum pack	-243.6	-69	312.6

Source: Sealed Air

Table 4-2: Typical Examples of Carbon (CO_2) Footprint Ratios of Food to Packaging

Food Item	CO_2 Ratio: Food to Packaging
Ham (cooked)	624:1
Beef	370:1
Cucumber	178:1
Whole chicken	114:1
Cheese	52:1
Fish	13:1
Pasta	7:1

Source: Sealed Air

The above tables illustrate the enormity of opportunities that exist to significantly improve resource use through packaging innovation, resulting in a more sustainable food system.

5 Industry Consultation

With an exhaustive cost-benefit analysis (CBA) being beyond the scope of this report, the industry consultations that occurred during the development of this report focused on exploring the core attributes of packaging and factors known to influence potentially significant reductions in food waste in retail, foodservice and amongst consumers. The decision was also made to primarily focus on fresh perishable products, where an extension in quality of only a few days provides proportionately more time for a product to be sold or used in the home compared to products possessing a longer shelf life.[94] With packaging known to have a particularly influential impact on reducing waste in fresh food types (with sufficient US data existing to enable a direct correlation to be made between the potential impact of multiple factors associated with packaging on reductions in food waste), the research focused on fruits and vegetables, bakery, meat and dairy.

5.1 Research Methodology

To provide a robust means of comparing relationships between a multiplicity of packaging related attributes and factors known to achieve measurable reductions in food waste, the research was designed to produce a voice of the customer (VOC) matrix. VOCs produce actionable insights that guide informed business decisions, including investments in product design, development and marketing. VOCs also enable progress to be monitored according to a series of clearly articulated goals.[95]

VOCs achieve this by enabling a series of attributes associated with achieving a purposeful outcome (the reduction of food waste) to be identified and prioritized from the standpoint of their ability to create customer recognized value. VOCs also create a common language, enabling market requirements to be better understood and translated into product or service designs than otherwise possible. In doing so, they provide “a highly useful springboard for product innovation.”[96] The food types, packaging attributes and factors known to result in potentially significant reductions in food waste are listed below in Table 5-1. The chosen food types reflect categories and data presented in Section 2.2; packaging attributes and means to reduce food waste reflect information contained in Section 3.

Table 5-1: Researched Food Types, Packaging Attributes, Means to Reduce Food Waste

Food Type	Packaging Attribute	Means to Reduce Food Waste
Fruits and vegetables	Reclosability	Increased shelf life
Bakery	Handling and storage instructions	Improve portion control
Meat	Packaging of previously unpacked products	Decreased leakage/spillage
Dairy	Passive packaging technologies*	Decreased damage
	Active packaging technologies*	
	Intelligent packaging technology***	
	Stronger secondary or tertiary packaging	
	Light-weighting/ recyclability	
	Changing materials (e.g. glass to plastic)	
	Pack sizing / portioning†	

* Passive packaging technologies include MAP, vacuum, controlled permeability.
** Active packaging technologies include odor scavenging, oxygen scavenging, gas absorbers.
*** Intelligent packaging technologies include sensors and indicators.
† Included in the list of attributes following its mention by multiple research respondents

Table 5-2 shows the 45 expert respondents who participated in the industry consultations, categorized by how they identified themselves. Suppliers include food manufacturers and distributors who supply both retail and foodservice though identified themselves according to their primary market.

Table 5-2: Expert Respondents

Occupation	Number of Respondents
Retailer	7
Retail supplier	3
Foodservice	2
Foodservice supplier	4
Packaging manufacturer, supplier	15
Consultant / researcher	5
NGO, incl. industry/trade association	7
Packaging media, communications	2
Total Respondents	**45**

The research utilized Likert[f] scale questions in two distinct surveys, the results of which enabled the population of the VOC matrix presented below in Figure 5-1. The first survey gauged respondents' views of the relationship between packaging attributes and known means of reducing food waste, both of which are listed in Table 5-1 above. A separate series of responses was gathered for each of the four types of food researched. The strength of relationships was assessed on a scale of 0-3 (0 = no relationship; 1 = minor relationship; 2= moderate relationship; 3 = significant relationship).

These surveys were completed by phone with targeted packaging and food industry experts, many of whom expanded on specific factors and personal experiences during discussions which typically lasted 30 minutes to one hour. A second survey asked respondents to rate on a scale of 1-3 (1 = minor; 2= moderate; 3 = significant) the potential impact of each of the four ways listed in Table 5-1 for reducing food waste. A separate series of responses was gathered for each of the four types of food researched. These surveys were completed online by experts from retail, foodservice, food manufacturing/distribution, packaging manufacturing and research/academia. All respondents were offered the opportunity to express views on the role of packaging to reduce food waste not covered in the survey.

Quantitative data provided by the 45 respondents was analyzed to calculate median scores for the combined effect that each of the four factors and ten packaging attributes were anticipated to have on driving reductions in US food waste. Median scores were used because they show the middle response, thereby preventing any overly optimistic (or pessimistic) responses to bias the research findings. Qualitative data was analyzed thematically to assist in interpreting the results.

[f] Description of Likert scale questions and their purpose

5.2 Research Results

This section presents aggregated research findings from the analysis of quantitative data, followed by insights into the most impactful means for reducing food waste in each of the fresh foods researched. Findings from the analysis of qualitative data are then discussed.

5.2.1 Quantitative Findings

The VOC matrix in Table 5-3 describes the aggregated impact that packaging can have on reducing food waste. In summary:

- Listed down the left-hand column of the matrix are packaging attributes.
- Listed across the top of the matrix are ways of reducing food waste.
- The second row from the top shows the impact that respondents believe each way to reduce food waste can have on the foods researched.
    - The columns listed under each of these four ways show the degree to which respondents associate a strong relationship existing between a packaging attribute and a way to reduce food waste.
- The third column from the left shows the cumulative effect that each packaging attribute can have on reducing food waste.
- The second column from the left shows the contribution that each attribute can make to enabling packaging to play an impactful role in reducing fresh food waste.
- The far-right column ranks, from 1 to 10, the importance of each packaging attribute for combating food waste.
- The bottom row shows the cumulative impact that packaging can have on each of the four ways known to produce reductions in food waste.

Table 5-3: VOC Matrix for Fresh Food

	Increased Shelf Life	Improved Portion Control	Decreased Leakage/ Spillage	Decreased Damage	Association Score	% Contribution to Reducing Food Waste	Ranked importance to reducing food waste
Potential impact on reducing FW	3	2	2.25	2			
Reclosability	2	3	2	1	19	11.2%	5
Handling and storage instructions	2	1	1	1.5	13	8.0%	8
Packaging of previously unpackaged products	2.5	2.25	2	2	21	12.4%	2
Passive packaging technologies	3	1.5	2.5	1.5	21	12.5%	1
Active packaging technologies	3	1.5	1.25	1	17	10.2%	6
Intelligent packaging technologies	2.5	1	1	1.25	14	8.6%	7
Stronger secondary or tertiary packaging	2.5	1	2	3	20	12.1%	3
Light-weighting / recyclability	1	1	1	1.25	10	5.9%	10
Changing materials	1.75	2.75	2	1.75	19	11.4%	4
Pack size / portions	1.5	3	0.5	0.5	13	7.6%	9
	65	36	34	30	165	100%	

Critical
Important

The matrix shows that the most impactful role that packaging can play in reducing food waste is by extending shelf life, followed by decreased leakage/spillage, improved portion control and decreased damage. The most effective way to reduce food waste is by utilizing passive packaging technologies, followed by packaging of previously unpackaged foods and stronger secondary or tertiary packaging. There is not a large difference in the relative importance of one or two packaging attributes versus all others; this finding indicates that there is a multiplicity of effects that packaging has on driving reductions in food waste. Extended shelf life, for example, is enabled through multiple attributes — some of which (e.g. stronger tertiary and secondary packaging, and changing materials) have a stronger direct impact on reducing damage or leakage/spillage.

Table 5-4 lists ways to reduce food waste in each category of food, in order of their identified impact. Each factor is listed left to right in order of their expected role for reducing waste in each food.

Table 5-4: Ranked Importance of Ways to Reduce Food Waste

Food category	#1 impact	#2 impact	#3 impact	#4 impact
Aggregated	Increased shelf life	Decreased leakage/spillage	Improved portion control	Decreased damage
Fruit & vegetables	Increased shelf life	Decreased damage	Decreased leakage/spillage	Improved portion control
Bakery	Increased shelf life	Improved portion control	Decreased damage	Decreased leakage/spillage
Meat	Increased shelf life	Decreased leakage/spillage	Improved portion control	Decreased damage
Dairy	Increased Shelf life	Decreased leakage/spillage	Improved portion control	Decreased damage

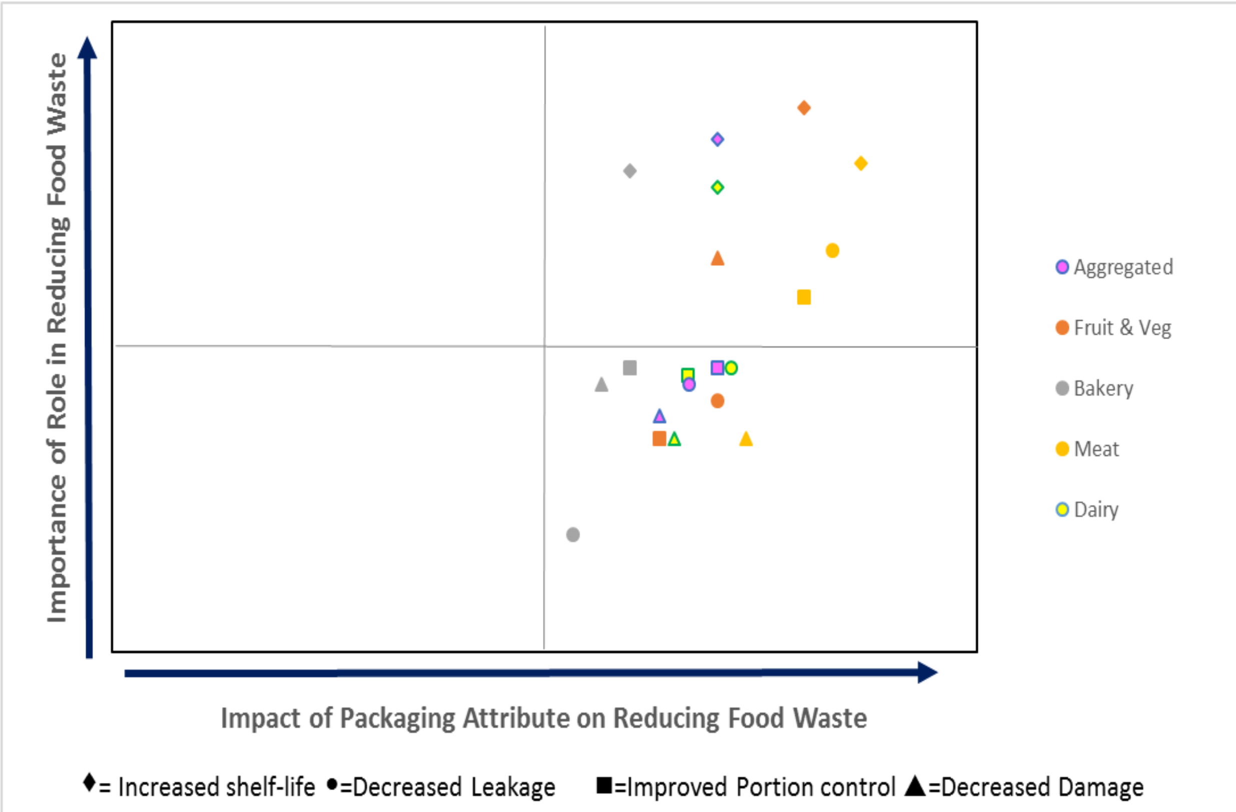
Table 5-5 lists, for each category of food, the packaging attributes identified as having the greatest impact on reducing food waste. Attributes are listed left to right in order of their expected impact.

Table 5-5: Top Four Packaging Attributes for Reducing Food Waste

Packaging attribute	#1 impact	#2 impact	#3 impact	#4 impact
Aggregated	Passive packaging technologies	Packaging of previously unpackaged products	Stronger secondary or tertiary packaging	Changing materials
Fruit & vegetables	Pack size, portions	Stronger secondary or tertiary packaging	Passive packaging technologies	Packaging of previously unpackaged products
Bakery	Packaging of previously unpackaged products	Stronger secondary or tertiary packaging	Pack size, portions	Changing materials
Meat	Stronger secondary or tertiary packaging	Packaging of previously unpackaged products	Passive packaging technologies	Reclosability
Dairy	Passive packaging technologies	Changing materials	Packaging of previously unpackaged products	Stronger secondary or tertiary packaging

To illustrate the scale of impact that packaging can have on reducing food waste in fresh foods, the above findings were plotted on a scatter chart. Figure 5-1 illustrates the important role packaging plays in reducing food waste. The impact that packaging has on extending shelf life has on driving reductions in food waste is particularly noticeable, with the identifiers all lying in the upper right quadrant. While variations exist in the relative impact of other packaging attributes for driving reductions in waste across each of the foods, the impact remains significant.

Figure 5-1: Impact of Packaging on Reducing Food Waste



Meat, followed by fruits and vegetables, would benefit the most from optimized packaging.

Meat, followed by fruits and vegetables, would benefit the most from optimized packaging. Monetarily, meat is the most valuable type of food wasted in the US. Meat also accounts for a significant proportion of the environmental footprint created by food waste. The longest extension in shelf life from optimized packaging would occur in fruit and vegetables. Fruit and vegetables represent the highest volumes of food waste presently going to landfill. While dairy then bakery may benefit comparatively less from optimized packaging, the role of packaging for enabling a reduction in waste remains significant.

The chart only shows the expected impact of the top four packaging attributes for each of the foods; it doesn't indicate the attributes that have a compounding effect on packaging's role in reducing food waste. For example: pack size and portioning result in less waste regardless of shelf life; stronger tertiary and secondary packaging leads to less food being disposed of due to damage, leakage or spillage; standardized labeling reduces accidental waste; and light-weighting / recyclability increases consumers' acceptance of packaging.

5.2.2 Qualitative Findings

The qualitative insights captured during the industry consultations shared a common theme: the opportunity to reduce US food waste through optimized packaging is typically underestimated.

The following four statements are indicative of those expressed during the industry consultations:

1. “USA lags Europe in the percentage of fresh fruits and vegetables sold packaged, (and) Europe is generally more environmentally conscious.” (Industry Association)
2. “Packaging is our best shot at reducing food waste!” (Packaging Material Developer)
3. “Especially in the produce section of the retail outlets, there's opportunity for packaging to reduce waste at the retail level.” (Packaging Manufacturer)
4. “Shelf life is important for our customers. However, the message about the strong role that packaging plays in extending shelf life is not getting out.” (Retailer)

Respondents described where they had seen clear benefits achieved from improved packaging. Of the examples provided, three in particular are worth noting:

1. Changing from modified atmosphere packaging (MAP) to active technology packaging more than doubled the shelf life of pasta. The financial benefits produced by a reduction in retail shrink more than offset any increase in packaging costs.
2. The foodservice industry has embraced flexible packaging for a range of items, such as freshpack tomatoes. The move eliminated a workplace health and safety issue (no sharp edges) and reduced the amount of packaging waste (volume and weight). In turn, this reduced waste handling costs, including lower landfill charges.
3. Portion sizing can increase the number of units sold by retailers. While the price (measured on a weight or volume basis) paid by consumers may be higher than if buying in bulk, consumers benefit by paying less overall than if buying bulk items — a proportion of which is wasted. Retailers and foodservice benefit from capturing a higher margin. They also benefit from a higher sales velocity and inventory turns, resulting in reduced shrink.

The above results further emphasize the extent to which US food waste could be reduced through improved packaging.

6 Packaging's True Role in Reducing Food Waste

6.1 Direct Benefits

Section 4.1 presented evidence on the extent to which the role of packaging for reducing US food waste has been underestimated. From reviewing research into 1) reductions in food waste achievable through packaging, 2) actual reductions in food waste achieved in other jurisdictions, 3) results from the industry consultations described above, and 4) the data presented in Section 2, the impact of optimized packaging on US food waste was estimated.

Indications for the scale of opportunities realizable in the US by optimized packaging include the following:

- A significantly higher percentage of available food is wasted by consumers in the US versus other jurisdictions.
- Fresh foods benefit the most from optimized packaging due to limited shelf life and their susceptibility to damage, spillage/leakage or contamination occurring along the value chain.
- A one-day extension in shelf life can translate to a five percent reduction in total UK food waste.
- A two to ten-fold increase in the shelf life of fresh foods is achievable by optimized packaging, equating to days, weeks or months longer than if foods are sold loose or traditionally packaged.
- Measurably less fresh food is sold packaged in the US compared to other developed nations.
- A strong correlation exists in the US between those foods that experience the highest levels of waste and those foods that are least likely to be sold packaged.
- Packaging attributes have a cumulative effect on reducing food waste.
- ReFED referenced packaging technologies that can reduce food waste by up to 35 percent.
- Improved packaging contributed to the 14:1 ROI produced by food waste reduction efforts implemented by retail, foodservice and food manufacturers/distributors.
- European retailers have reduced waste (shrink) from optimized packaging. In Austria, an average improvement of 15 percent waste was achieved across a range of fresh foods.
- In chicken, the use of MAP and portioned packaging was estimated as offering a 30 percent reduction in consumer level waste occurring in the UK.

That many of the outcomes cited in the report have been achieved in Europe (which is measurably ahead of the US in the percentage of foods sold packaged and in utilizing optimized packaging to reduce food waste) speaks to the greater impact that optimized packaging could have in the US. Based on the findings regarding the combined effects of optimized packaging and an increase in the percentage of foods sold packaged, a scenario of 20 percent reduction in the volume of food waste occurring in meat and fruits and vegetables is considered achievable. While bakery and dairy are often already sold prepackaged (and typically less susceptible to erroneous handling than fruits, vegetables and meat from a shelf life and damage perspective), a 10 percent reduction in food waste through optimized packaging is considered a likely scenario. Given the data presented on the impact of improved packaging, and the starting point for improving upon current US packaging and food industry behaviors compared to comparable developed nations, these estimates are considered conservative.

To provide an indicative assessment of the potential impact of utilizing packaging to address US food waste, the same anticipated reduction of 20 percent and 10 percent were applied to retail, foodservice and consumers. The estimates on what this reduction in US food waste for fruit, vegetables, bakery, meat, dairy and eggs equates to in value and volume is presented in Table 2-4.

Annual reduction in waste would save households $17.02 billion, and retail and foodservice $3.87 and $9.69 billion dollars, respectively.

Shown below in Table 6-1, the scenarios of a 20 percent reduction in wasted fruits, vegetables and meat, along with a 10 percent reduction in wasted bakery, dairy and eggs, equates to 7.68 million tons with a value of $30.58 billion dollars. This annual reduction in waste is equivalent to the weight of 21 Empire State buildings. Monetarily, this reduction in waste would save households $17.02 billion, and retail and foodservice $3.87 and $9.69 billion dollars, respectively. Household savings alone is equivalent to the median income of 305,000 US homes.[g]

Table 6-1: Reductions in US Food Waste Estimated by Value ($ Billion) and Volume (Million Tons)

Food waste (FW) by market segments	FW retail		FW foodservice		FW household		Total	
	$ Value	Volume	$ Value	Volume	$ Value	Volume	$ Value	Volume
Fruit and veg	1.35	0.52	2.88	1.11	4.76	1.84	8.99	3.47
Bread and bakery	0.65	0.19	1.07	0.32	1.55	0.47	3.28	0.98
Dairy and eggs	0.62	0.27	1.12	0.49	1.72	0.75	3.46	1.52
Meat	1.26	0.15	4.61	0.53	8.98	1.04	14.86	1.72
TOTAL	**3.87**	**1.13**	**9.69**	**2.46**	**17.02**	**4.09**	**30.58**	**7.68**

[g] Based on 2015 median income of $55,775.

The conservative nature of the monetary estimates is underlined by four further points:

1) The foodservice related benefits captured by reducing food waste from packaging optimization was based on retail values — which is likely a moderate proxy for the real value of food waste occurring in foodservice (see Section 2.2).

2) Packaging has the most impact on household waste. Achieving a higher percentage reduction in household food waste would offset the 10 percent or 20 percent scenarios shown above not being met in retail or foodservice.

3) The report pertains only to food waste going to landfill. The analysis did not include food waste going to animal feed, industrial uses, composting, anabolic digestion, etc.

4) The estimates do not include additional costs associated with food waste (see section 4.1). In retail and foodservice, associated costs include transaction costs and lost revenue, along with disposal costs. Disposal costs are also incurred from consumer-generated waste, often charged in the form of municipal taxes.

6.2 Environmental Benefits

Using data produced by FAO, USDA and ReFED, an estimate was produced of the environmental impacts achievable through the reductions in US food waste detailed above. Methodologies developed by FAO were followed to calculate the carbon footprint (GHG emissions measured in CO_2 equivalent) and the blue water footprint (consumption of surface and ground water resources).

6.2.1 Carbon CO_2

FAO estimates that North America and Oceania account for 8 percent of global food wastage, which, according to their data, equals 126.77 million tonnes. It was estimated that in this region food waste accounts for 330.96 million tonnes of CO_2 equivalent emissions. Therefore, we can estimate that every tonne[h] of food waste produced 2.61 tonnes of CO_2 equivalent emissions. This equates to an average of 2.37 tons of CO_2 per ton of food waste in the US.

A reduction of 7.68 million tons of food waste equates to a reduction in 18.2 million tons of CO_2 emissions.

Using FAO's value for CO_2, a reduction of 7.68 million tons of food waste equates to a reduction in 18.2 million tons of CO_2 emissions. Adjusted for inflation, this amounts to $1.98 billion in value.

[h] "Tonne" refers to European measurement, or 1,000 kg; "ton" refers to US measurement, or 2,000 lb.

6.2.2 Surface and Ground Water

Similarly, FAO estimated that food waste in North America and Oceania consumes 16.26km^3 of surface and ground water resources, meaning that every ton of food waste equates to 116m^3 of wasted water.

A reduction of 7.68 million tons in food waste equates to a reduction in water usage of 236 billion gallons.

Using FAO's estimates, a reduction of 7.68 million tons in food waste equates to a reduction in water usage of 0.89km^3 or approximately 236 billion gallons. This is equivalent to the water contained in almost 358,000 Olympic swimming pools.

7 Conclusion

This report investigated the role that optimized packaging can play in reducing US food waste in retail, foodservice and amongst consumers. Focused primarily on fresh foods – where packaging is proven to reduce waste through means such as extending shelf life, portion sizing and minimizing losses through damage – the study found that prior research has underestimated the role of packaging in reducing US food waste.

Based on research findings, the report concludes with scenarios of achieving a 20 percent reduction in wasted fruits, vegetables and meat, and a 10 percent reduction in wasted bakery, dairy and eggs being achievable from optimized packaging. These estimates are considered conservative. To quantify:

- This would result in a 7.68 million tons' reduction in food waste, equivalent to the weight of 21 Empire State buildings.
- Worth a total of $30.58 billion dollars, the reduction in food waste would result in households saving $17.02 billion, and retail and foodservice $3.87 and $9.69 billion dollars, respectively.
- The household savings alone are equivalent to the median income of 305,000 homes in 2015.
- The environmental benefits produced by a 7.68 million ton reduction in food waste equate to a $1.98 billion reduction in GHG and saving the water contained in just under 358,000 Olympic swimming pools.

Reasons for the scale of opportunities that are realizable from improved packaging include 1) the significantly higher percentage of available food wasted by consumers in the US versus other jurisdictions, and 2) that measurably less fresh food is sold prepackaged in the US compared to other developed nations. A strong correlation exists between those foods least likely to be sold prepackaged and those foods experiencing the highest levels of waste. This fact underlines the scale of opportunities achievable through improved packaging.

Industry consultations identified packaging attributes expected to have the greatest impact on driving reductions in food waste. Respondents deemed that the most impactful attribute was the use of passive packaging technologies (e.g. MAP), followed by a) the packaging of previously unpackaged products, b) stronger secondary or tertiary packaging, c) reclosability, and d) changing to alternative packaging materials. The report presented these findings in the form of a VOC matrix and scatter plot, which the food industry can use as a springboard to guide packaging innovations that would result in measurable reductions in US food waste.

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